

Centrality dependence of some characteristics of relativistic nuclear interactions and percolation cluster formation

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Abstract

Some of the centrality experiments indicate regime change and saturation in the behaviour of characteristics of the secondary particles produced in relativistic nuclear interactions. We discuss that the responsible mechanism to explain the phenomena could be the percolation cluster formation and we expect appearance of deconfinement in the cluster.

1 Introduction

The experimental results on the centrality [1]-[8] and energy [9]-[10] dependence of particle production in heavy ion ultrarelativistic collisions coming from the heavy ion physics program at the SPS CERN [11] and RHIC BNL [12] show regime change and saturation which could serve as evidence for the existence of a transition to a new phases of strongly interacting matter.

Let us consider some examples. The experimental ratios of the average values of multiplicity of K^+ -, K^- -, ϕ - mesons, and Λ -hyperons to the average values of multiplicity of π^\pm - mesons as a function of centrality coming from SPS CERN are presented in paper [1]. The centrality was fixed using the average number of participant nucleons ($\langle N_{part} \rangle$). They could obtaine that the ratios are increase with centrality and saturate in the area of $\langle N_{part} \rangle > 60$.

A compilation of measurements of yields at midrapidity for the most abundant hadron species for central nucleus-nucleus (Au-Au or Pb-Pb) collisions are presented in paper[10]. As the centrality selection differs between various measurements, they have scaled the data for the same number of participating nucleons, $N_{part}=350$. It is the point of regime change and saturation effect from these data too.

The examples show the regime change and saturation in the behaviours of some characteristics of events as a function of centrality and colliding energies.

If the regime change observed in the different experiments would take place unambiguously two times, this would surely be the most direct experimental evidence seen so far pointing to a phase transition from the normal hadronic matter to a phase of deconfined quarks and gluons. However, second point of regime change has not been observed clearly, moreover the effect taken place for hadron-nuclear and for nuclear- nuclear interactions too. Let us met the data coming from the hadron-nuclear experiments.

2 Hadron-nuclear interaction

In paper [3] the results are presented from BNL experiment E910 on pion production and stopping in proton-Be, Cu, and Au collisions as a function of centrality at a beam momentum of 18 GeV/c. The centrality of the collisions was characterized using the measured number of grey tracks, N_{grey} , and a derived quantity, ν , the number of inelastic nucleon-nucleon scatterings suffered by the projectile during the collision. They obtained that the π^- multiplicity increases approximately proportionally to N_{grey} and ν for all three targets at small values of N_{grey} or ν and saturates with increasing N_{grey} and ν in the region of more high values of N_{grey} and ν . They could observe that the wounded-nucleon (WN) model [3] did not explain the results. It was obtained that the measured Λ yield increased faster than the participant scaling expectation for $\nu \leq 3$ and then saturated and the deviation in strange particle production from a wounded-nucleon scaling. The same result have been obtained by BNL E910 Collaboration for K_s^0 and K^{+-} mesons emitted in p+Au reaction.

Now let us consider some example on nuclear-nuclear interactions.

3 Nuclear-Nuclear Interaction

The average values of multiplicity $\langle n_s \rangle$ for s - particles produced in Kr + Em reactions at 0.95 GeV/nucleon as a function of centrality are presented in paper [5]. They could saw that there are two regions in the behaviour of the values of $\langle n_s \rangle$ as a function of N_g (a number of grey particles) for the Kr+Em reaction. In the region of : $N_g < 40$ the values of $\langle n_s \rangle$ increase linearly with N_g , here the cascade evaporation model (CEM) [13] also gives the linear dependence but with the slope less than the experimental one; $N_g > 40$ the CEM gives the values for average n_s greater than the experimental observed ones, the last saturates in this region, the effect could not be described by the model. It have been previously observed in emulsion experiments [6].

It is very important that the regime change has been indicated in the behaviour of heavy flavor particles production in ultrarelativistic heavy ion collisions as a function of centrality. Next paragraph connects with these data.

4 Regime change and saturation in charmonium production.

The ratio of the charmonium to Drell-Yan cross-sections has been measured by NA38 and NA50 SPS CERN as a function of the centrality of the reaction estimated, for each event, from the measured neutral transverse energy E_t [8]. Whereas peripheral events exhibit the normal behavior already measured for lighter projectiles or targets, the charmonium shows a significant anomalous drop of about 20% in the E_t range between 40 and 50 GeV.

Other significant effect which was be seen by authors was a regime change in the E_t range between 40 and 50 GeV both for light and heavy ion collisions and saturation.

5 Results.

So we could see that:

1. The above motioned regime change had been observed:
 - at some values of centrality and colliding energy, as some critical phenomena;
 - for hadron-nuclear , nuclear-nuclear interactions and ultrarelativistic ion collisions;
 - in the range energy from SIS energy up to RHIC energy;
 - almost for all particles (from mesons, baryons, strange particles up to charmonium).
2. After point of regime change the saturation is observed.
3. The simple models (such us WN and CEM) which usually used to describe the high energy hadron-nuclear and nuclear-nuclear interactions could not explain the existing of the regime change point and saturation.

6 Discussion

The results show that the dynamic of the phenomena should be same for hadron-nuclear, nuclear-nuclear and heavy ion interactions independent of the energy and mass of the colliding nuclei and the types of particles.

The responsible mechanism to describe of the above mentioned phenomena could be statistical and percolation ones because phenomena have a critical character. In talk [14] was presented the complicate information about the using statistical and percolation models to explain the experimental results coming from heavy ion physics.

The regime change and saturation was observed for hadron-nuclear and light nuclear-nuclear interaction where it is very hard and practically impossible to reach the necessary conditions to apply the statistical theory (the statistical models have to give the more strong A-dependences than percolation mechanisms). That is way we believe that the responsible mechanism for explain the phenomena could be the percolation cluster formation [15].

Big percolation cluster could be formed in the hadron-nuclear, nuclear-nuclear and heavy ion interactions independent of the colliding energy. But the structure and the maximum values of the reaching density and temperature of hadronic matter could be different for different interactions depend on the colliding energy and masses in the framework of the cluster.

Paper [16] discusses that deconfinement is expected when the density of quarks and gluons becomes so high that it no longer makes sense to partition them into color-neutral hadrons, since these would strongly overlap. Instead we have clusters much larger than hadrons, within which color is not confined; deconfinement is thus related to cluster formation. This is the central topic of percolation theory, and hence a connection between percolation and deconfinement seems very likely [17]. So we can see that the deconfinement could occur in the percolation cluster. Author explain the charmonium suppression as a result of deconfinement in cluster too.

7 Appearance of the critical transparency of the strongly interacting matter.

The heavy flavour particles are the most sensitive to phase transition and to formation of QGP. So the observing of the effects connected with formation and decay of the percolation clusters in heavy ion collisions at ultrarelativistic energies and studying the correlation between these effects and the effect of the charmonium suppression could be unambiguously confirmation of the reaching the deconfinement of strongly interacting matter in cluster.

Percolation cluster is a multibaryon system. With increasing the centrality of collisions its size and masses could increase as well as its absorption capability. So, for example, we could see the decreasing the particle yields with increasing of the centrality. But instead it we could see the saturation. It could mean that after point of regime change the conduction of strongly interacting matter is increase and it becomes the superconductor. The reason is that the conduction of the matter increases and the matter becomes a superconductor [18] due to the formation of percolation cluster. Because of in those systems the nucleons (quarks) must be bound as a result of the percolation.

8 Search for signal

The critical changing of transparency of the strongly interacting matter could influence on the characteristics of secondary particles changing them.

Angular distribution of secondary particles could be more sensitive to the changing of the transparency of the matter and to the formation the big cluster. Because of the probability of big percolation cluster formation have to be biggest in the central zone of the collisions. So the particles which emitted in different distance from central zone of collisions will be exposed to different changing. It could lead to the critical change of the angular correlations of the particle production because of the transparency the particles will be absorbed differently depending on the angular. In talk [19] $\frac{dN}{dy}$ distributions for light charged particles (π, p, d, t) from Au+Au collisions in the range 2 - 8 AGeV at the AGS (E895 Experiment) are presented. They wrote that as collision energy increases, baryons retain more and more of the longitudinal momentum of the initial colliding nuclei. This is characterized by a flattening of the invariant particle yields over a symmetric range of rapidities, about the center of mass, and it is an indicator of the onset of nuclear transparency.

9 Summary

So, in our opinion to confirm the deconfinement in cluster it could be necessary to study the centrality dependence of behaviour of heavy flavour particles yield (appearance the point of regime change and suppression) and simultaneously, critical increasing of the transparency of the strongly interacting matter.

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